D6.3 Post-Implementation Environmental Assessment of Selected Educational Establishments

Funding scheme	EU-H2020-Grean Deal, H2020-LC-GD-2020-3		
Project	ECF4CLIM, European Competence Framework for a Low Carbon Economy and Sustainability through Education		
Project number	101036505		
Project Coordinator	CIEMAT, Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas		
Start Date of the Project	01.10.2021	Duration of project	48 months
Contributing WP	WP6: Testing the ECF: Participatory Evaluation		
Tasks	Task 6.3: Environmental evaluation of the selected educational establishments		
Dissemination Level	Public		
Due date	2025 July 18		
Submission date	2025 July 18		
Responsible partner	IST		
Contributing organizations	CIEMAT, USE, JYU, UAB, MedaResearch, QUE		
Authors:	Tiago Faria, Marta Almeida, Joana Lage, Antonis Stratis, Anna Lehtonen, Carmen Lago, José Antonio Becerra, Josep Espluga Trenc, Marian Constantin, Niina Mykrä, Yolanda Lechon Perez		
Version	1.0		

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036505

TABLE OF CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

1. EXECUTIVE SUMMARY

The deliverable 6.3 presents the post-implementation assessment of the environmental performance of the demonstration sites participating in the ECF4CLIM project. Building upon the baseline audit conducted under Deliverable 4.3 and the interventions implemented throughout the project (WP5), this assessment aims to evaluate both the short-term and long-term impacts of these interventions in key environmental sectors.

Unlike the baseline assessment, which provided a comprehensive but uniform evaluation across all demonstration sites, this final assessment adopts a sector-based approach tailored to each intervention carried out. As each school implemented different types and numbers of interventions, not all environmental sectors were evaluated in all schools. The analysis is therefore structured by sector—including energy, waste, water, green spaces, green procurement, transport, and indoor air quality—and includes only those schools where relevant data and interventions exist.

Short-term impacts were evaluated using predefined Key Performance Indicators (KPIs), reused from the baseline phase, whenever comparable data was available. These KPIs capture quantifiable improvements in areas such as energy consumption, waste production, and water use.

In addition to this quantitative assessment, the report includes a qualitative analysis of long-term impacts. These reflect the potential of the interventions to create enduring changes in environmental awareness, behavior, competencies, and institutional practices.

This dual approach—combining KPI-based evaluation with a broader reflection on long-term transformation—reflects the project's commitment to participatory and adapting to each school's context. The findings demonstrate the value of school-specific actions and provide a basis for further scaling and replication of the ECF4CLIM approach.

2. LEGAL NOTICE

3. ABOUT THE PROJECT

The ECF4CLIM develops, tests and validates a European Competence Framework (ECF) for transformational change, through a multidisciplinary, transdisciplinary and participatory process, which aims to empower the educational community to take action against climate change and towards sustainable development.

This project intends to apply a novel hybrid participatory approach, rooted in participatory action research and citizen science, and to co-design the ECF in demonstration sites and universities, by:

1) elaborating an initial ECF, supported by crowdsourcing of ideas and analysis of existing ECFs;
2) establishing the baseline of individual and collective competences, as well as environmental performance indicators.
3) implementing practical, replicable and context adapted technical, behavioral, and organizational interventions that foster the acquisition of competences.
4) evaluating the ability of the interventions to strengthen sustainability competences and environmental performance; and
5) validating the ECF.

The proposed ECF is unique in that it encompasses the interacting STEM (Science, Technology, Engineering, and Mathematics) -related, digital and social competences, and systematically explores individual, organizational and institutional factors that enable or constrain the desired change. The novel hybrid participatory approach provides the broad educational community with an ECF adaptable to a range of settings, new ways of collaboration between public, private and third-sector bodies, and innovative organizational models of engagement and action for sustainability.

To encourage learning-by-doing, several novel tools were co-designed with and made available to citizens, including a digital platform for crowdsourcing, IoT solutions for real-time monitoring of selected parameters, and a digital learning space. Participation of various small and medium enterprises (SMEs) in the consortium maximizes the broad adoption and applicability of the ECF for the required transformational change towards sustainability.

3.1. Who we are

The ECF consortium consists of ten partners (Table *1*). The project is coordinated by Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas - CIEMAT.

Table 1- ECF4CLIM partners.

Name	Country	Logo
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (**CIEMAT)**	ES	
Instituto Superior Técnico. University of Lisbon (**IST)**	PT	
Universidad de Sevilla (**USE)**	ES	
University of Jyväskylä (**JYU)**	FI	
Universitat Autònoma de Barcelona (**UAB)**	ES	
Meda Research Ltd (**MedaResearch)**	RO	
Instituto de Soldadura e Qualidade (**ISQ)**	PT	
Trebag Szellemi Tulajdon Es Projektmenedzser Korlatolt Felelossegu Tarsasag (**REBAG)**	HU	
ENLITIA Energy Services SA (**ENLITIA)**	PT	
Que Technologies Kefalaiouchiki Etaireia (**QUE)**	GR	

4. METHODOLOGY

The post-implementation environmental performance evaluation of the demonstration sites was designed to measure the effectiveness of the interventions implemented throughout the ECF4CLIM project. The assessment was guided by the same hybrid and participatory approach used in previous phases, while introducing new elements: the focus on intervention-based evaluation, and the inclusion of both quantitative (KPI-based) and qualitative (long-term impact) analysis.

The methodology was built on four main phases, adapted from the baseline audit (D4.3):

- Mapping of interventions by school and sector
- Data collection and KPI computation
- Qualitative reflection on long-term impacts
- Integration of results and cross-sectoral analysis

4.1. Demonstration sites

A total of 13 demonstration sites across Portugal, Spain, Romania, and Finland participated in the ECF4CLIM project and were involved in the final environmental performance evaluation. These are the same schools assessed in the baseline audit (D4.3), and where co-designed interventions were implemented and monitored as part of WP5.

The schools differ significantly in terms of educational level, geographical location, institutional structure, and available resources. This diversity was a major strength of the project, allowing the methodology to be tested and validated in a variety of real-life conditions. It also highlighted the need for a flexible and adaptive evaluation approach, shaped by each school's specific context, priorities, and capacities.

The demonstration sites cover the full educational spectrum — from pre-school to university — and are distributed as follows:

- Portugal: 3 schools in Lisbon district – two in Loures and one in Lisbon
- Spain: 3 schools in Madrid, Seville, and Barcelona
- Romania: 4 schools in Dragasani, Mioveni, Sercaia, and Pitesti
- Finland: 3 schools – two in Tampere and one in Jyväskylä

The complete list and characteristics of the demonstration sites are provided in Table 2, and their geographical distribution is shown in Figure 1.

Only the schools that carried out measurable interventions in one or more environmental sectors were considered in each respective analysis. While all 13 schools were part of the overall process, not all appear in every sectoral chapter, depending on the nature and scope of their actions.

Throughout the process, the project followed a participatory approach. Local Sustainability Competence Teams (SCTs) and Sustainability Competence Committees (SCCs) played a key role in identifying needs, co-designing actions, and interpreting results. This involvement helped foster ownership of the process and ensured that both interventions and their evaluation were aligned with the values and priorities of each school community.

Table 2- List of the ECF4CLIM demonstration sites.

Code	Country	City	Type of school*	School area (m^2)	No. Students
S1	Portugal	Loures	Primary, Lower and upper secondary school	35270	741
S2		Loures	Primary and Lower secondary school	25888	901
S3		Lisbon	Higher education	80824	11334
S4	Spain	Seville	Lower and upper secondary school	14823	498
S5		Madrid	Pre-school and Primary school	11039	642
S6		Barcelona	Higher education	2625000	662
S7	Romania	Dragasani	Primary and secondary school	4873	960
S8		Mioveni	Primary and secondary school	5800	1584
S9		Sercaia	Primary and Lower secondary school	4189	265
S10		Pitesti	Higher education	10659	1943
S11	Finland	Tampere	Upper secondary school	15000	1012
S12		Tampere	Lower secondary school	4725	897
S13		Jyväskylä	Higher education	10245	14900

*International Standard Classification of Education

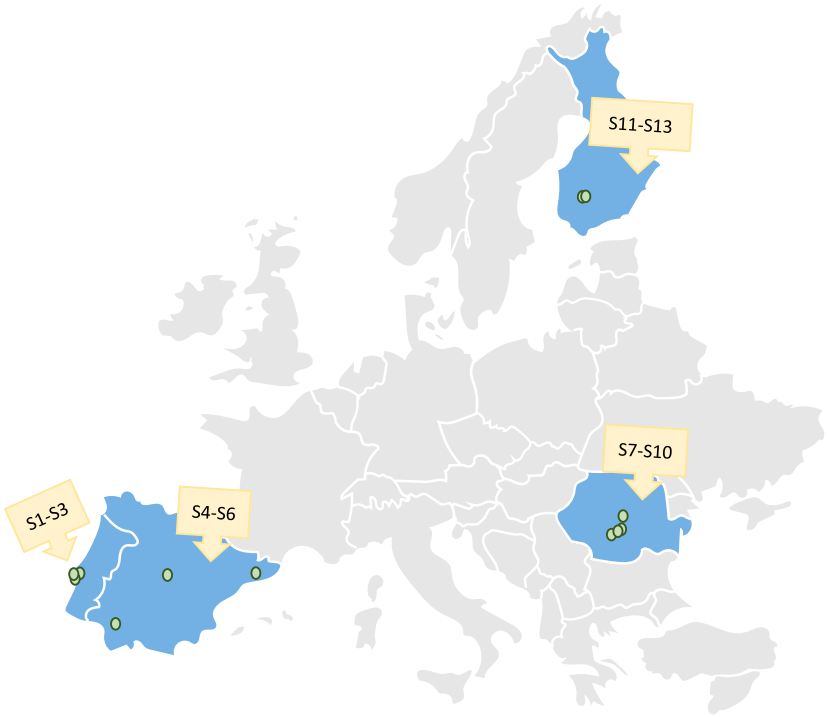

Figure 1- Location of the ECF4CLIM demonstration sites.

4.2. Intervention Mapping and Sector Selection

Each school implemented a unique set of interventions, co-designed with their local communities through the SCT/SCC processes. These actions targeted specific environmental sectors according to the priorities and context of each school. As a result, this final evaluation does not attempt to reassess all sectors uniformly across schools but rather focuses on those where interventions were implemented and data was available to support impact assessment.

The evaluation is organized by sector, and within each sector, the report includes:

- A brief description of the interventions per school.
- A KPI-based analysis of short-term impacts (when applicable);
- A qualitative reflection on long-term impacts.

Table 3 below lists the full set of environmental sectors and associated KPIs as defined in Deliverable 4.3. These KPIs were designed to allow consistent and comparable assessment across different schools and contexts.

Table 3 - Environmental sectors and KPIs defined in the ECF4CLIM methodology.

Environmental Sector	KPIs	Description
Energy	KPI-E1 to KPI-E6	Energy consumption, cost, renewable share, CO_2 emissions
Water	KPI-Wr1 to KPI-Wr4	Water consumption and cost per area and student
Waste	KPI-W1 to KPI-W3	Waste generation, recycling, reuse volumes
Green Spaces	KPI-GS1 to KPI-GS7	Tree count, green area per student, CO_2 sequestration, chemical use
Green Procurement	KPI-GP1 to KPI-GP7	Equipment efficiency, recycled materials, staff training, local suppliers
Transport	KPI-T1 to KPI-T4	Bicycle and EV parking, public transport, commuting CO_2 emissions
Indoor Air Quality	–	Not KPI-based; observational and qualitative data only

Note: While this table includes all KPIs defined by the ECF4CLIM methodology, only those related to energy, water, and waste were applied in this deliverable (D6.3). These were the sectors where schools implemented interventions with an immediate effect and where post-intervention data was available. For the remaining sectors (transport, green procurement, green spaces, indoor air quality), KPI-based assessment was not carried out, although some qualitative reflections are included in Section 4. For KPI definitions and formulas, see Table 4 in Deliverable 4.3.

4.3. Data Collection and Tools

Data collection for the post-implementation evaluation was conducted between February and May 2025, using multiple sources and tools:

- Utility data (electricity, water bills before/after intervention)
- Observational audits (visual inspection of interventions)

- Quantitative monitoring (via IoT systems where installed)
- Feedback from school communities (surveys, informal interviews)
- Standardized templates for KPI data entry
- Forms for qualitative analysis of long-term impacts by partners and the school community

Despite these efforts, several data limitations affected the scope of the quantitative analysis. In some schools, key data (such as type of waste produced) was unavailable or not directly comparable to the baseline. Timing constraints and variations in intervention scale also affected the ability to measure short-term impacts with precision.

To ensure quality and relevance, the evaluation prioritized reliability data. Sectors or schools with insufficient data were excluded from KPI analysis but still considered in the broader qualitative assessment.

All partners responsible for demonstration sites were involved in completing the data collection and reporting, with coordination and technical support from IST.

4.4. KPI Calculation and Comparison

The short-term impacts of the interventions were assessed using quantitative KPIs, following the definitions and calculation methods established in Deliverable 4.3 (Section 3.2.1.1 and Table 4). These KPIs provide a structured and comparable way to evaluate changes in environmental performance over time. In this final evaluation, KPIs were applied only in sectors where relevant interventions took place and where reliable post-intervention data was available.

The results were translated into normalized KPI scores using the 0–5 scale defined in the baseline. This scale enabled the measurement of relative improvements, even where the absolute values varied greatly across schools. For example, a school with high baseline water consumption could still demonstrate significant progress if post-intervention reductions were proportionally large.

In cases where data was unavailable, incomplete, or not comparable, the KPI was not calculated. Instead, the evaluation relied on qualitative insights, ensuring that no relevant interventions were excluded from the final analysis due to data limitations.

Unlike the baseline assessment, this deliverable does not include a global ECF4CLIM score. The focus is placed on sector-specific impacts and school-level analysis, in line with the intervention-based approach adopted for this final evaluation.

4.5. Long-Term Impact Assessment

While KPIs offer valuable insights into the short-term and measurable outcomes of the interventions, many of the expected results of the ECF4CLIM project aim to generate deep and lasting transformations, which often become visible only over time. These include changes in school culture, daily routines, learning environments, and stakeholder engagement.

To capture these aspects, partners completed a form for each intervention. These forms were used to reflect on non-quantifiable outcomes and anticipated long-term effects, considering the specific context and objectives of each school.

A key element of this analysis was the development of both individual and collective competencies within the school community.

- Individual competencies refer to increased awareness, knowledge, skills, and behavioral changes among students, teachers, and staff. These were often associated with themes such as energy saving, waste reduction, or sustainable consumption.
- Collective competencies emerged when the school, as a system, adopted new routines, created sustainability teams, improved communication structures, or embedded environmental topics into the curriculum or institutional decisions.

These long-term impacts, while not directly measurable through KPIs, were often reported by partners as the most significant and lasting outcomes of the interventions. In some cases, they led to broader involvement of families, municipalities, or external stakeholders, reinforcing the participatory and context-sensitive nature of the ECF4CLIM approach.

By recognizing and documenting these effects, this evaluation goes beyond technical results and highlights the capacity of schools to act as living laboratories for sustainability transitions — where change happens not only through data, but through people, practices, and shared purpose.

5. ENVIRONMENTAL PERFORMANCE: RESULTS AND DISCUSSION

5.1. Waste

Overview of Interventions

The waste sector was one of the most commonly addressed areas across the ECF4CLIM demonstration sites, reflecting both the urgency of improving waste management practices in educational settings and the sector's strong potential for educational engagement. A total of 9 out of 13 schools implemented one or more interventions related to waste prevention, improved waste separation, promotion of circular economy principles, and raising awareness within the school community.

Schools implemented a wide range of measures, including the introduction or reinforcement of waste separation systems, student-led awareness campaigns, creative reuse projects, and initiatives to reduce plastic use. Some actions were supported by infrastructure (e.g., new bins, collection points), while others focused on behavior change through communication and engagement.

Table 4 presents an overview of the schools that implemented waste-related interventions, including the number of distinct actions reported per school.

Table 4 – Number of waste-related interventions implemented in the ECF4CLIM demonstration sites

Country	School code	No. of waste-related interventions
Portugal	S1	2
Portugal	S2	2
Portugal	S3	1
Spain	S4	1
Spain	S5	1
Spain	S6	1
Finland	S11	1
Finland	S12	1

These interventions were co-designed and implemented through participatory processes involving the Sustainability Competence Teams (SCTs) and Sustainability Competence Committees (SCCs). While differing in scale and focus, they all contributed to strengthening environmental literacy, shared responsibility, and collective action within the schools.

Short-Term Impact Assessment

Despite the relatively low-cost and localized nature of most interventions in this sector, short-term environmental and educational impacts were consistently reported across the demonstration sites. These effects, while not always quantifiable, represent an important shift in behavior, awareness, and school culture.

Reported impacts include:

- Increased awareness among students and staff about proper waste sorting and the environmental consequences of poor waste management.
- More consistent separation of recyclable and non-recyclable waste, supported by improved infrastructure and clearer visual cues (e.g., signage and color-coded bins).
- Active engagement of students in daily waste management routines, including monitoring roles, which reinforce sustainability competences through practice.
- Visibility of environmental topics across the school through peer-to-peer campaigns, posters, and events.
- Strengthened sense of responsibility and collaboration through classroom-based competitions and shared goals.

These outcomes contributed to the development of both individual sustainability competences (e.g., systems thinking, critical thinking, and responsibility) and collective competences (e.g., participation, cooperation, and action-oriented engagement).

In addition to these qualitative results, the environmental performance in the waste sector is being assessed through a set of Key Performance Indicators (KPIs) based on quantitative data collected before and after the interventions. The KPIs selected for this sector include:

- KPI-W1 – Volume of urban solid waste produced per student;
- KPI-W2 – Volume of waste recycled per student;

The waste sector showed notable progress among the demonstration sites that actively engaged in monitoring, reducing, and managing their waste production. The analysis focuses on five schools (S2, S4, S5, S6, and S11), for which comparable data were available at baseline and after interventions.

Figure 2 presents the values for KPI-W1 and KPI-W2, which assess the volume of waste produced (non-recyclable and reusable) and the volume of waste recycled per student, respectively. These indicators provide insight into the schools' waste generation and recycling behaviors.

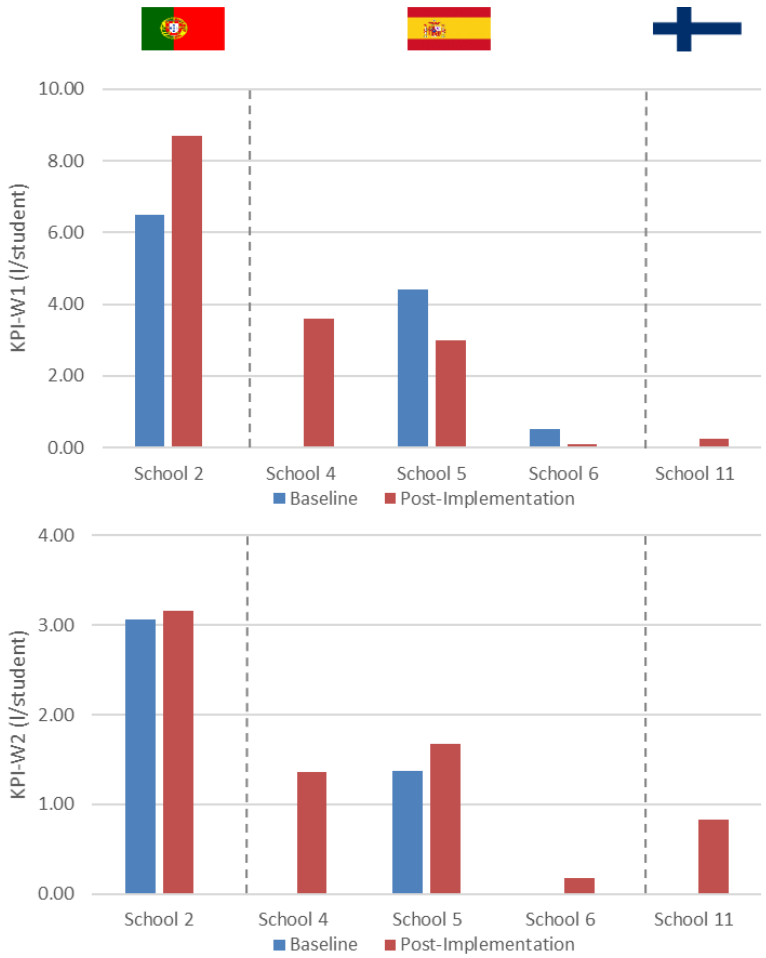

Figure 2 - Weekly urban solid waste (non-recyclable and non-reused) (KPI-W1) and recyclable waste (KPI-W2) produced in each school per student.

All evaluated schools show improvements in these KPIs compared to baseline. Schools S4, S5, and S6 notably reduced their total waste production per student while increasing their recycling rates, indicating effective implementation of waste reduction and separation practices. While the final waste score for School S2 remained stable, the individual KPIs reveal a more complex scenario. The slight increase in total waste volume per student (KPI-W1) post-implementation can be attributed to ongoing changes in the school's waste management practices during the project period. On one hand, the introduction of more recycling bins—an outcome of the ECF4CLIM interventions—and increased environmental awareness fostered through competitions have positively influenced recycling behaviors. On the other hand, changes in waste collection logistics by the municipal waste management company, such as shifting collection points from inside the school to the exterior, have caused staff to store longer inside the school and expend additional effort moving waste externally. These operational shifts can have contributed to fluctuations in measured waste volumes and complicate direct comparison with baseline data. Nonetheless, other KPIs demonstrate progress in recycling and waste separation, indicating that the school community continues to advance toward better waste management.

Figure 3 illustrates the final waste score. This indicator reveals that all schools, except S2, have improved their overall waste management performance since the baseline. The increase in waste reuse, though modest, signals emerging adoption of circular economy principles such as reuse programs and second-hand initiatives within the school communities.

It is worth noting that some baseline data involved conversion from mass to volume units using regional density factors, which may introduce some variability. Despite this, the consistent ascending trend in both individual KPIs and the final score confirms the positive impact of awareness campaigns, technical measures, and community engagement activities focused on waste management.

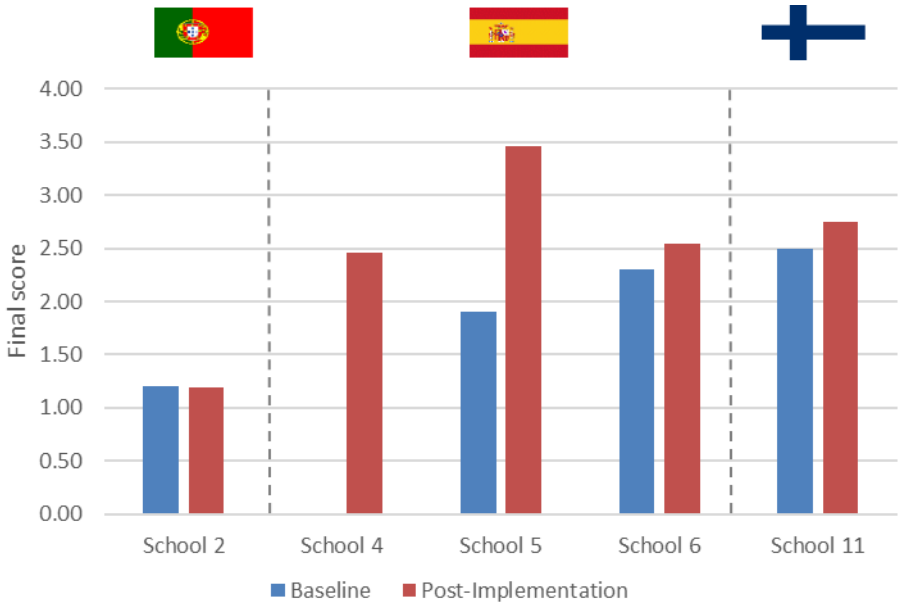

Figure 3- F score for the waste sector.

Overall, the demonstration sites have made meaningful strides toward reducing waste generation per student and increasing recycling and reuse, demonstrating growing environmental literacy and commitment. These improvements establish a solid foundation for further sustainability efforts and highlight the success of the ECF4CLIM project's interventions in fostering responsible waste management practices in educational settings.

Long-Term Environmental Impacts

While short-term effects often translate into immediate behavioral changes or improved infrastructure, the long-term impacts of the waste-related interventions are more closely linked to shifts in school culture, educational practices, and the internalization of sustainability values by the school community. The schools expect a variety of outcomes that go beyond the project's duration.

Several schools anticipate lasting improvements in waste management practices, supported by the institutionalization of new routines. These include the regular use of sorting bins, integration of waste separation in school rules or building design, and the maintenance of awareness campaigns as part of annual school events.

In schools where students were directly involved in the implementation or monitoring of interventions, such as classroom competitions or awareness initiatives, a stronger culture of shared responsibility and participation emerged. Teachers and coordinators expect these practices to continue, not just because of infrastructure, but because they are now embedded in the way the school operates and the way students interact with their environment.

Some schools highlight that the interventions triggered cross-generational learning, with students discussing new habits with their families and spreading awareness beyond the school. This multiplier effect — although difficult to measure — is seen as crucial for the long-term transformation of community attitudes towards waste.

In terms of educational impact, many schools report that these actions contributed to a more experiential and competence-based approach to sustainability, aligning with the ECF4CLIM methodology. Waste-related activities allowed students to apply knowledge to real-life contexts, fostering systems thinking, responsibility, and critical reflection — all central elements of the GreenComp framework.

Finally, several schools noted that these small-scale waste interventions helped to build momentum and confidence to address other environmental issues in the future. The successful implementation of simple measures, supported by student participation and visible results, has encouraged both staff and students to take on more ambitious projects related to sustainability.

5.2. Water

Overview of Interventions

The water sector was addressed in a more limited and indirect manner compared to others within the ECF4CLIM demonstration sites. Only a few schools implemented interventions explicitly focused on water use, water savings, or awareness-raising actions related to water management. These included, for example, educational campaigns to promote responsible consumption, and activities that calculated water savings from circular practices such as reuse of clothes. Nonetheless, the interventions implemented reflect growing concern over water consumption, the importance of responsible use of natural resources, and the potential of schools to promote behavioral change in this area. A total of 4 out of 13 schools implemented one intervention directly related to water conservation, water efficiency or water sustainability education.

In addition to these direct interventions, several schools—particularly in Finland—developed broader sustainability education actions where water was one of multiple environmental topics addressed. These interventions, while not exclusively focused on water, promoted transversal competences, awareness, and behavioral change that can positively influence water consumption in the long term. For the sake of clarity and methodological consistency, only interventions with a clear and explicit focus on the water sector have been counted in the Table 5.

The reported actions varied in type and scope. Some focused on technical solutions to reduce water use, such as the installation of pressure-reducing devices in taps. Others were educational in nature, including integration of water sustainability themes into curricula or awareness-raising campaigns among students and staff. In higher education institutions, interventions also explored the link between water and sustainable engineering practices.

Table 5 presents an overview of the schools that implemented water-related interventions, indicating the number of distinct actions reported per school.

Table 5 – Number of water-related interventions implemented in the ECF4CLIM demonstration sites

Country	School code	No. of water-related interventions
Portugal	S2	1
Spain	S4	1
Spain	S5	1
Romania	S8	1

Short-Term Impact Assessment

Despite the smaller number of interventions explicitly dedicated to water, the short-term impacts observed or anticipated across the schools suggest meaningful engagement with water-related sustainability issues. These impacts were primarily educational and behavioral, with some technical improvements implemented at the school level.

Reported short-term effects include:

- Increased awareness among students, teachers, and staff about water scarcity, the environmental footprint of water-intensive goods (such as clothing), and the need for more efficient water use;
- Promotion of reuse practices—such as second-hand clothing markets—that indirectly reduce water consumption by lowering demand for water-intensive production.
- Incorporation of water topics into sustainability curricula, enabling students to understand local and global water issues and their connection to climate change, consumption, and personal behavior.
- Adoption of small-scale technical solutions, such as tap regulators, aimed at reducing water waste within school buildings.
- Student-led communication campaigns to promote responsible water consumption at school and within households.

Although these outcomes are not always quantifiable through direct metrics, they reflect growing environmental literacy and the diffusion of water-conscious habits in daily school life. The transversal nature of some of the interventions—particularly in Finland—also suggests a potential multiplier effect as knowledge and attitudes spread across different school actors and activities.

To complement this qualitative analysis, quantitative performance will be assessed using a limited set of KPIs where applicable. These include:

- KPI-WR1 – Water consumption per useful area
- KPI-WR2 – Water consumption per student
- KPI-WR3 – Water costs per useful area
- KPI-WR4 – Water costs per student

Meaningful quantitative data was available only for one demonstration site in Romania (School S8). The KPIs calculated for this school include water consumption per useful area (KPI-WR1), water consumption per student (KPI-WR2), water cost per useful area (KPI-WR3), and water cost per student (KPI-WR4).

The annual values measured after the intervention showed only minor differences compared to the baseline values, as summarized below (Table 6):

Table 6 - Comparison of water-related KPIs for School 8, post-intervention versus baseline.

KPI	Baseline	Post-intervention
Water consumption (m^3/m^2)	0.71	0.72
Water consumption (m^3/student)	4.58	4.22
Water cost (€/m^2)	1.59	1.72
Water cost (€/student)	10.29	10.09

While the similarities in these values may partly reflect external factors such as the COVID-19 pandemic affecting water use patterns during the baseline period, the slight reduction observed in water consumption per student and water cost per student suggests positive movement towards more efficient water use.

It is important to note that the baseline period spanned from 2017 to 2021, thus including pre-pandemic years as well as the COVID-19 pandemic period. The altered attendance patterns and changes in building usage during the pandemic may have influenced water consumption levels in the latter part of the baseline, potentially leading to atypical measurements. Therefore, the post-intervention figures are likely more representative of typical operational conditions.

Since the number of students increased between the baseline and post-intervention assessments, while the useful building area remained constant, the observed water consumption indicators reflect differing dynamics. The nearly stable water consumption per square meter (0.71 to 0.72 m^3/m^2) suggests consistent overall facility use and maintenance. In contrast, the decrease in water consumption per student (4.58 to 4.22 m^3/student) indicates improved water use efficiency relative to the growing student population.

Similarly, water costs per square meter showed a slight increase (1.59 to 1.72 €/m^2), likely linked to operational factors or price changes, whereas costs per student decreased marginally (10.29 to 10.09 €/student), reinforcing the interpretation of enhanced efficiency in water management at the individual level.

These results align with the qualitative evidence from the interventions, which included educational campaigns on water conservation and technical measures such as installation of tap pressure regulators. The combination of behavior changes and small-scale infrastructure improvements is expected to support gradual water savings in the long term.

Given the limited quantitative data available, these findings should be interpreted cautiously but are encouraging indicators of initial progress in the water sustainability efforts within the ECF4CLIM demonstration sites.

Long-Term Environmental Impacts

The long-term impacts of the water-related interventions implemented in the ECF4CLIM demonstration sites are primarily associated with changes in awareness, values, and daily behaviors that can gradually lead to more sustainable water consumption practices. Although most interventions did not involve major infrastructural transformations, they contributed to creating an educational environment in which the responsible use of water is understood as a key component of environmental citizenship.

Schools integrated water-related topics into sustainability education efforts, fostering a deeper understanding of the connections between individual choices, resource consumption, and environmental

impacts. Through activities such as awareness campaigns, reuse initiatives, and sustainability-themed pedagogical events, students and teachers were encouraged to reflect on their own water footprint and adopt more conscious habits. This educational approach is expected to influence future decision-making, both within the school community and beyond.

In higher education settings, the inclusion of water-related content in transdisciplinary curricula and sustainability modules is likely to shape the competencies and priorities of future professionals, reinforcing the role of water in broader sustainability transitions. Although the extent of such impacts is difficult to measure at this stage, the interventions helped establish a foundation for lasting behavioral and institutional change.

By making water a visible and recurring topic in school life—whether through direct interventions or as part of broader sustainability efforts, these actions support the emergence of long-term environmental responsibility and cultural shifts that extend well beyond the duration of the project.

5.3. Transport

Overview of Interventions

The transport sector was one of the least directly addressed areas within the ECF4CLIM demonstration sites. Despite the significant role that mobility plays in environmental sustainability, particularly in relation to air pollution, greenhouse gas emissions, and energy consumption, only one school implemented a concrete intervention explicitly focused on transport.

This limited engagement may be due to the infrastructural and policy constraints often associated with sustainable transport measures in school environments. Unlike sectors such as waste or water, transport-related changes often require coordination with external actors (e.g., municipalities, transit authorities), involve more substantial logistical challenges, or fall outside the direct control of school administrations.

The sole transport-related intervention was implemented in School 1 from Portugal and focused on promoting active mobility among students by ensuring that all children could learn how to ride a bicycle. While this action may appear modest in scope, it carries strong long-term potential for behavioral change, fostering a culture of sustainable mobility from an early age.

Short-Term Impact Assessment

Due to the very limited number of transport interventions, short-term environmental impacts in this sector are not observable across the demonstration sites. The intervention in Portugal, involving bicycle lessons for students, did not include measurable impacts within the project period. However, it represents a foundational step toward promoting active mobility, particularly in underserved communities where students may not otherwise have access to this essential life skill.

Short-term educational benefits include increased awareness of alternative, low-impact transportation methods and the inclusion of cycling as a viable and healthy mode of transport in students' daily lives. The initiative may also help normalize sustainable mobility within the broader school culture, although these outcomes are largely qualitative and expected to unfold over time.

Long-Term Environmental Impacts

The long-term impact of the transport-related intervention implemented in Portugal lies in its potential to foster a cultural and behavioral shift toward sustainable mobility. By teaching all children how to ride a bicycle, the school promotes the use of active transport from an early age, especially in communities where such opportunities may not otherwise exist. While the immediate environmental effects may be limited, the intervention contributes to developing skills and confidence that can influence students' future transportation choices.

Over time, as more students become comfortable with cycling, this can lead to a gradual reduction in car dependency, particularly for short-distance travel to and from school. Such a shift can result in lower greenhouse gas emissions, improved air quality in urban environments, and reduced noise pollution. Furthermore, the initiative supports broader goals related to public health, as increased physical activity among children is linked to numerous health benefits.

By normalizing cycling as a viable and accessible mode of transport, the intervention also helps cultivate a shared responsibility for environmental sustainability within the school community. Although this transformation is difficult to measure in the short term, it contributes to a longer-term vision in which sustainable mobility becomes an embedded practice in everyday life. In this sense, the action serves not only as a mobility initiative but also as a catalyst for broader environmental citizenship and intergenerational change.

5.4. Green Spaces

Overview of Interventions

The green spaces sector was addressed in a limited but meaningful way across the ECF4CLIM demonstration sites. The institutions implemented interventions specifically targeting the creation, improvement, or educational use of green areas within or near the school grounds. These actions reflect a growing interest in reconnecting students with nature, promoting biodiversity, and enhancing the educational and social potential of outdoor spaces.

A total of 4 out of 13 schools reported one or more interventions explicitly related to green spaces. These included the construction of school gardens, the greening of outdoor learning areas, and awareness campaigns promoting the use and preservation of green infrastructure.

While the scale of these interventions varied, all shared a common goal: to make green spaces a more visible and functional part of the school environment. Some projects aimed to create edible gardens maintained by the school community, while others introduced vegetation in previously unused areas to improve aesthetics and ecological value. In certain cases, these green spaces also served as platforms for interdisciplinary learning, combining environmental education with health promotion, science, and citizenship.

Table 7 presents an overview of the schools that implemented green space-related interventions, and the number of distinct actions reported.

Table 7 – Number of green space-related interventions implemented in the ECF4CLIM demonstration sites

Country	School code	No. of green space-related interventions
Portugal	S1	1
Portugal	S3	1
Spain	S4	3
Spain	S5	1

Short-Term Impact Assessment

The short-term impacts of the green space interventions implemented in the ECF4CLIM demonstration sites were significant in terms of educational engagement, local biodiversity promotion, and improvement of the school environment. Most interventions focused on awareness-raising and the functional creation of small green areas within school premises, often with student participation in design or maintenance. These actions helped to enhance the visibility of nature-based solutions in the school context and provided a platform for experiential learning and community interaction.

Some schools introduced new planted areas or gardens, aiming to increase vegetation coverage and improve local microclimates. In others, green spaces were used as educational tools, allowing students to observe ecological processes, understand the benefits of permeable surfaces, or reflect on biodiversity. In all cases, the emphasis was not only on environmental benefits but also on fostering care, responsibility, and a sense of place among students.

These interventions were a symbolic and pedagogical value recognized by participating schools. Improvements in the visual quality of schoolyards, increased use of outdoor areas for learning activities, and positive student feedback were among the reported short-term effects. In some cases, these efforts contributed to broader goals such as community involvement or intergenerational learning, particularly when gardening activities or greening campaigns engaged families or local partners.

To assess the measurable impacts of the green space-related interventions, two main KPI scores were calculated: the green space usage score (GS1) and the annual CO_2 sequestration score (GS2). These scores aggregate several underlying KPIs detailed in Deliverable 4.3, including but not limited to:

- Number of trees per non-covered area (KPI-GS1)
- Number of trees per student (KPI-GS2)
- Green area as a percentage of non-covered area (KPI-GS3)
- Green area per student (KPI-GS4)
- Annual CO_2 sequestration per non-covered area (KPI-GS5)

Other related KPIs such as total chemicals used for maintenance (KPI-GS6) and CO_2 emissions from maintenance activities (KPI-GS7) were not used in this assessment due to insufficient data.

Only two demonstration sites in Spain provided the necessary data to calculate these green space scores. The two Portuguese schools with green space interventions could not be included in this quantitative analysis because ongoing construction prevented accurate assessment of their green area layouts.

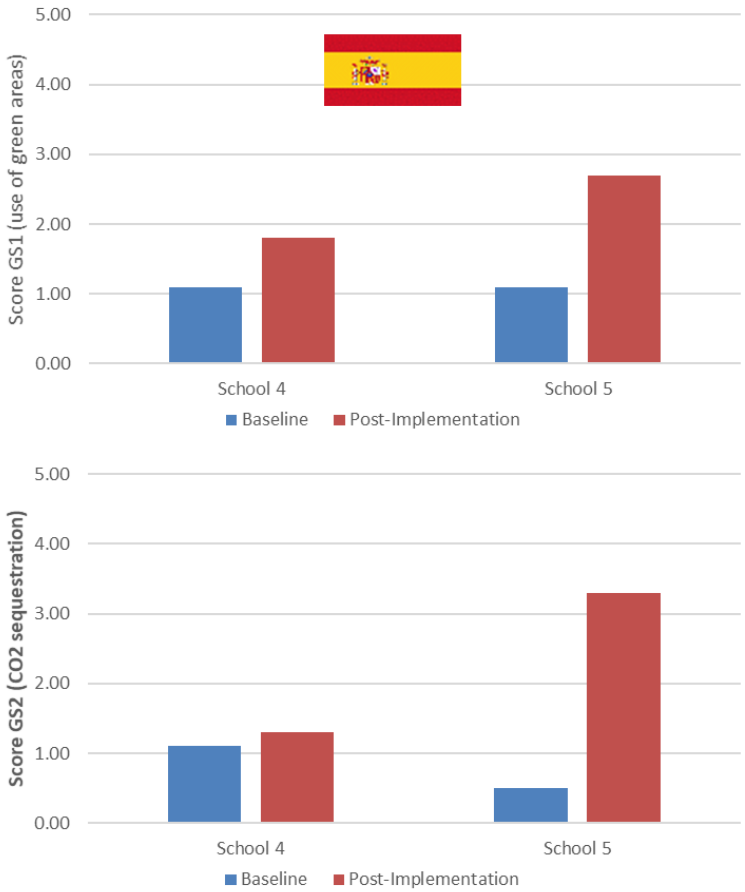

Figure 4 - Green spaces scores (0-5) of the demonstration sites

Comparing the post-intervention data with the baseline, clear improvements are observed. For the green space usage score (GS1), which reflects the green space available per student, baseline values increased from 1.1 to 1.8 and 2.7 respectively in these schools, indicating a significant expansion or enhancement of usable green spaces accessible to students. Similarly, the annual CO_2 sequestration score (GS2) rose from baseline values of 1.1 and 0.5 to 1.3 and 3.3 respectively, reflecting an increased capacity of the green spaces to capture and store carbon dioxide (Figure 4). These positive trends highlight concrete environmental benefits of the interventions, contributing not only to improved school environments but also to broader climate change mitigation goals through enhanced carbon sequestration.

Long-Term Environmental Impacts

The green spaces interventions implemented in ECF4CLIM demonstration sites are expected to generate long-lasting impacts that go beyond immediate environmental benefits. By transforming underutilized or degraded areas into gardens, shaded outdoor classrooms, and recreational green zones, these actions contribute to the regeneration of the school environment and promote a stronger connection with nature among students and staff.

Several schools explicitly noted that these green spaces are not only seen as physical improvements, but as long-term educational tools. The integration of gardening and biodiversity into school routines helps to instill values of care, observation, and ecological responsibility in students from a young age. This experiential

learning fosters a deeper understanding of natural cycles and the importance of preserving green infrastructure, particularly in increasingly urbanized areas.

In some contexts, the intervention aimed to create a more liveable and climatically resilient school/campus, using green spaces as a response to heat island effects and to promote comfort and well-being. While the tangible effects on temperature or microclimate may take time to become evident, the visibility of these spaces and the participatory process through which they were designed contribute to long-term institutional awareness and prioritization of green infrastructure in future planning.

More broadly, the consistent presence of natural elements in school life—whether through tree planting, shaded structures, or garden projects, can influence future behaviors and choices. Students who grow up in greener learning environments may be more likely to advocate for or design similar spaces in their own communities later in life. In this sense, the green space interventions not only change the physical layout of the school, but also shape a mindset that values environmental quality, well-being, and sustainability.

5.5. Green Procurement

Overview of Interventions

The green procurement sector was addressed in a significant number of ECF4CLIM demonstration sites, reflecting an increasing awareness of the environmental impact associated with institutional purchasing practices. A total of 6 out of 13 schools implemented one or more interventions with a clear and explicit focus on green procurement, including actions related to sustainable food systems, critical consumption, reuse of materials, and promotion of eco-friendly products and services.

These interventions varied widely in scope and strategy. In some cases, they focused on the direct implementation of greener procurement practices—such as prioritizing local and organic food, reducing single-use items, or integrating environmental criteria into purchasing decisions. In other cases, the approach was more educational or strategic, aiming to instill values of responsible consumption through school-wide campaigns, curriculum innovation, and institutional planning. Several interventions also addressed food systems from a sustainability perspective, combining environmental, health, and ethical dimensions.

Table 9 provides an overview of the schools that reported at least one green procurement-related intervention.

Table 8 – Number of green procurement-related interventions implemented in the ECF4CLIM demonstration sites

Country	School code	No. of green procurement-related interventions
Portugal	S3	1
Spain	S4	1
Spain	S6	2
Finland	S11	3
Finland	S12	1
Finland	S13	1

Short-Term Impact Assessment

Most interventions in the green procurement sector were of an exploratory or awareness-raising nature, aiming to introduce sustainability criteria into purchasing decisions or to promote more conscious consumption habits among students and staff. These actions were often integrated into broader sustainability education efforts, making procurement an entry point to discuss environmental impact and systemic change.

In the short term, the environmental effects of these interventions were limited and largely non-quantifiable. Schools reported small-scale behavioral changes—such as increased reuse of school materials, attention to food origin and waste, and experimentation with vegetarian meals—as initial signs of change. In some cases, schools began to reflect on procurement choices at an institutional level, questioning current suppliers and exploring alternatives with lower environmental impact.

However, no school was able to provide concrete metrics or data that would allow for the calculation of short-term improvements. This is expected given the nature of the sector: measurable environmental benefits from green procurement typically emerge over longer periods and require systemic adjustments in purchasing frameworks, supplier relationships, and budgetary procedures.

Nonetheless, the groundwork laid by these initial actions is essential for future transformation. By making procurement decisions more visible and connected to environmental outcomes, these interventions opened space for longer-term institutional shifts and helped cultivate a culture of responsibility in daily operations.

Long-Term Environmental Impacts

The green procurement interventions implemented during the ECF4CLIM project has a long-term potential lies in the cultural and institutional shifts they help to initiate. By introducing sustainability principles into school purchasing decisions, however informally, encouraged reflection on the broader environmental implications of everyday operations, including the acquisition of food, supplies, and teaching materials.

Several schools integrated green procurement considerations into wider educational strategies, often linked to circular economy principles, sustainable food systems, or responsible consumption. Through awareness-raising campaigns, student-led projects, and participatory events, schools engaged their communities in rethinking what and how resources are consumed. In some cases, actions such as the introduction of vegetarian meals, creative reuse of existing materials, or thematic discussions about the sustainability of food supply chains, helped translate abstract ideas into tangible, relatable experiences.

While structural changes to procurement processes are inherently gradual and often constrained by administrative and legal frameworks, the educational foundation laid by these interventions can influence future decision-making. Teachers, students, and school management teams who are exposed to these concepts are more likely to consider environmental criteria in future purchases, advocate for greener alternatives, and shape institutional policies over time.

In higher education settings, green procurement actions were often framed within broader strategic objectives—such as developing sustainable food systems or designing transversal learning environments that integrate consumption-related topics. These initiatives hold promise for multiplying impact beyond campus boundaries, as they may shape the competencies and attitudes of future professionals.

Ultimately, the legacy of these interventions will depend on their continuity and reinforcement. While the immediate impacts were limited, their contribution to embedding sustainability thinking into daily practices and institutional culture represents a critical step toward longer-term environmental responsibility.

5.6. Air Quality

Overview of Interventions

Air quality was not one of the initially prioritized sectors in the baseline assessment of the ECF4CLIM project, primarily due to the absence of monitoring infrastructure in most schools. As a result, no quantitative KPIs were defined or measured at that stage. However, the relevance of this topic has grown throughout the project, particularly as air pollution in schools is increasingly recognized as a health and learning concern.

Some demonstration sites identified air quality as an important issue and took steps to address it. A few explicitly implemented interventions aimed at monitoring or improving indoor air quality. These measures include the installation of air quality sensors or curricular and awareness-raising activities that addressed air quality in the broader context of environmental health and sustainable building design.

It is worth noting that, although only a small number of schools formally classified these actions under the "air quality" category, all most schools have since acquired real-time indoor air quality sensors and are collecting data on parameters such as CO_2, VOCs, particulate matter, temperature, and humidity.

Table 10 summarizes the schools that implemented specific interventions related to air quality.

Table 9 – Number of air quality-related interventions implemented in the ECF4CLIM demonstration sites

Country	School code	No. of air quality-related interventions
Portugal	S3	1
Spain	S4	1
Spain	S5	1

Short-Term Impact Assessment

The short-term impacts of the air quality interventions are diverse but primarily educational and infrastructural. Schools that implemented monitoring systems reported increased awareness among students and staff regarding indoor environmental conditions. By visualizing real-time air quality data, school communities became more engaged in practices that improve ventilation, reduce emissions indoors, and adjust behaviors accordingly.

Some schools implemented technical solutions, such as adiabatic bioclimatic systems, to reduce indoor temperatures and improve air circulation. In such cases, while direct impacts on air pollutant concentrations may not have been immediately measured, improvements in perceived air comfort and temperature stability were achieved.

Furthermore, several schools reported that discussions about air quality—whether through student-led campaigns or curriculum integration—fostered greater understanding of the link between air pollution, health, and climate change. These activities helped develop transversal competencies such as critical thinking, data interpretation, and sustainable behavior.

Air Quality Data Analysis

Throughout the project, indoor air quality monitoring was progressively implemented across several demonstration sites, enabled by the installation of real-time sensor networks described in Deliverable 4.3. These systems continuously measured key parameters such as carbon dioxide (CO_2) and fine particulate matter (PM2.5), providing a robust dataset for analysis.

The data reveal notable differences across countries and school types. Finnish schools consistently displayed low average CO_2 concentrations (Figure 5), typically ranging between 400 and 500 ppm, reflecting the presence of effective mechanical ventilation systems that ensure reliable air renewal year-round. In contrast, schools in Portugal and Romania frequently recorded average CO_2 levels exceeding recommended thresholds of 1250 ppmv, indicative of insufficient ventilation during periods of high occupancy. Spanish schools presented intermediate results, with average concentrations generally below legal limits but episodic exceedances during peak occupancy, pointing to intermittent ventilation challenges.

Regarding PM2.5 concentrations (Figure 6), Portuguese and Romanian schools exhibited averages and peak values substantially exceeding World Health Organization guidelines (5 µg/m³ annual mean and 15 µg/m³ 24-hour mean). Spanish schools, while showing generally lower average PM2.5 levels, registered significant peaks. Finnish schools maintained low PM2.5 levels with occasional spikes, aligning with their consistent ventilation performance.

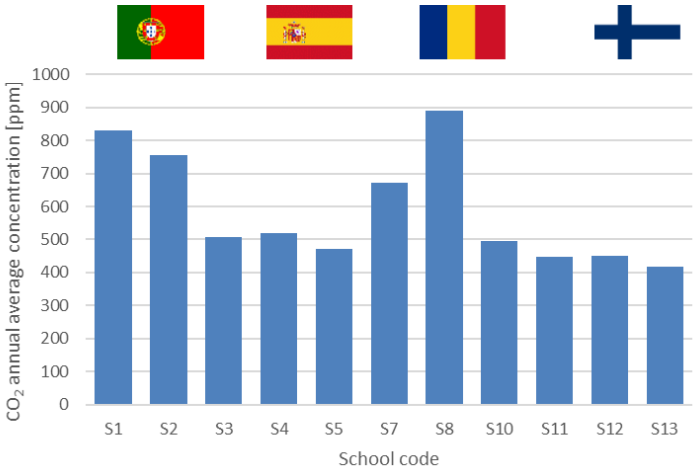

Figure 5 – CO2 annual concentration by Demonstration site (ppm)

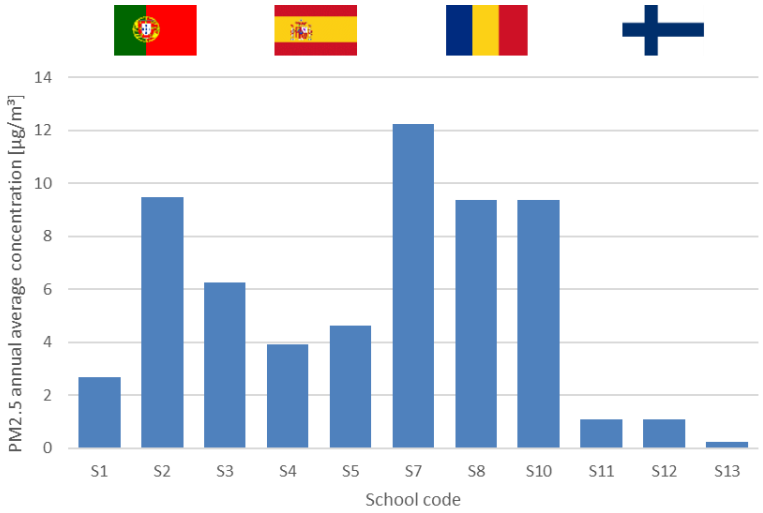

Figure 6 – PM2.5 annual concentration by Demonstration site (µg/m3)

Seasonal variation was evident in most countries. Portugal, Spain, and Romania showed marked increases in both CO_2 and PM2.5 concentrations during colder months, attributable to reduced natural ventilation as windows and doors remain closed to preserve indoor temperature. Conversely, warmer months facilitated improved ventilation, resulting in lower pollutant levels. Finnish schools exhibited minimal seasonal fluctuation, further emphasizing the effectiveness of their mechanical ventilation systems.

A strong positive correlation between CO_2 and PM2.5 concentrations was observed, underscoring the critical role of adequate ventilation in mitigating indoor air pollution. Poor ventilation allows for the accumulation of both gaseous and particulate pollutants, thereby exacerbating health risks and reducing indoor air quality.

These findings have important implications for school environments. Elevated CO_2 concentrations have been associated with diminished cognitive function, increased student absenteeism, and various health symptoms including headaches and respiratory issues. Exposure to elevated PM2.5 levels increases the risk of respiratory and cardiovascular diseases, with children being particularly vulnerable. Consequently, there is an urgent need to improve ventilation infrastructure, prioritize the deployment of mechanical ventilation systems where feasible, and implement continuous air quality monitoring to ensure safe and healthy learning environments. Further long-term studies are recommended to assess the effectiveness of mitigation strategies and to guide future interventions.

Long-Term Environmental Impacts

In the long term, air quality interventions are expected to generate cultural and institutional change in schools. By introducing air monitoring tools and engaging school communities in interpreting and responding to data, these interventions helped embed environmental health considerations into daily school life.

Increased awareness of indoor pollution sources—such as overcrowding, inadequate ventilation, or cleaning products—can lead to behavioral adaptations, including opening windows more frequently, reducing the use of pollutants indoors, or rearranging classroom layouts for better airflow.

More importantly, schools that included air quality sensors have started institutionalizing its monitoring and management. This includes planning for the continued use of sensors, data-informed decisions for space usage, and integration of air quality themes into science, health, and environmental curricula.

These practices have the potential to extend beyond the project timeline. Students equipped with the ability to understand and act on environmental data are likely to carry this awareness into their homes and future workplaces, contributing to a broader culture of prevention and environmental responsibility.

5.7. Energy

Overview of Interventions

The energy sector was the most extensively addressed area across the ECF4CLIM demonstration sites, reflecting the urgent need to reduce energy consumption and transition to renewable energy sources within educational institutions. This sector presented the greatest diversity in types of interventions, as well as the highest number of participating schools, demonstrating a strong commitment across different countries and educational levels.

A total of nine out of the thirteen demonstration sites implemented one or more interventions specifically targeting energy efficiency improvements, renewable energy production, or energy-related educational and awareness activities. These measures ranged from the installation of photovoltaic (PV) solar panels, which directly contribute to renewable energy generation, to thermal comfort enhancements such as double glazing, thermal blinds, fans, and innovative climatization systems designed to reduce heating and cooling demands.

Alongside these physical infrastructure upgrades, many schools developed and integrated educational programs and awareness-raising campaigns aimed at building knowledge, skills, and positive attitudes toward sustainable energy among students, teachers, and staff. These programs included training sessions, workshops, monitoring activities of installed PV systems, and inclusion of energy sustainability topics in the curriculum, fostering an informed and engaged school community.

The geographic and institutional diversity of the demonstration sites — spanning from primary and secondary schools to universities across Portugal, Spain, Romania, and Finland — highlights the adaptability and relevance of these energy interventions in various contexts. While some interventions focused primarily on technical solutions to reduce energy use and carbon emissions, others emphasized the educational dimension, ensuring that the impacts extend beyond infrastructure to influence long-term cultural and behavioral change.

Table 11 summarizes the number of energy-related interventions reported by each demonstration site.

Table 10 – Number of air quality-related interventions implemented in the ECF4CLIM demonstration sites

Country	School Code	No. of Energy-Related Interventions
Portugal	S1	1
Portugal	S2	1
Portugal	S3	1
Spain	S4	2
Spain	S5	1
Spain	S6	1
Romania	S7	1
Romania	S9	1
Romania	S10	2

Short-Term Impact Assessment

The energy-related interventions implemented in the demonstration sites produced a range of short-term impacts, both measurable and qualitative, that demonstrate immediate benefits and set the foundation for longer-term improvements. Technical measures, such as the installation of photovoltaic panels and improvements in building insulation (including double glazing and thermal blinds), resulted in observable reductions in energy consumption and associated carbon emissions. Where available, energy bills and monitoring systems provided data to quantify these savings, supporting the effectiveness of the physical upgrades.

Beyond measurable energy savings, educational and engagement activities played a critical role in raising awareness and building competences among students, teachers, and school staff. Participatory approaches, such as training sessions on solar energy technologies and sustainable climatization systems, as well as hands-on monitoring of installed systems, enriched the learning experience and empowered the school community to understand and actively contribute to energy sustainability.

Other short-term impacts included increased visibility of energy sustainability efforts within schools, which fostered a culture of environmental responsibility and motivated peer-to-peer learning. Students influenced their families and wider communities by sharing knowledge and promoting renewable energy and energy-saving behaviors. Furthermore, the incorporation of energy-related topics into curricula and school projects helped to contextualize technical interventions, linking them to broader climate change and sustainability challenges.

Collectively, these short-term outcomes reflect a multifaceted approach combining infrastructure upgrades with education and community engagement — an approach that enhances both the technical and social dimensions of energy sustainability in schools.

To quantify the short-term impacts, the following KPIs were applied:

- KPI-E1 – Final energy consumption per useful area (kWh/m²)
- KPI-E2 –Final energy consumption per student (kWh/student)
- KPI-E3 – Renewable energy production percentage (%)
- KPI-E4 –Energy cost per useful area (€/m²)
- KPI-E5 – Energy cost per student (€/student)
- KPI-E6 – Annual carbon footprint per student ($kgCO_2$/student)

Although more schools have installed photovoltaic panels or conducted energy-related actions, only a subset provided sufficient data for KPI calculation. The available data focus on six schools: S2, S3, S4, S6, S7, and S9.

Energy Consumption

The energy consumption KPIs reveal notable differences among the demonstration sites, reflecting diverse building typologies, climatic conditions, and operational practices. Universities such as School S3 and S6 exhibit the highest consumption per area and per student. This is explained by the complexity of their buildings, which include specialized spaces such as laboratories with high-energy-consuming equipment operating continuously. Furthermore, these institutions function for extended hours — sometimes up to 14 hours daily — encompassing both teaching and extracurricular activities, which naturally elevates energy demand.

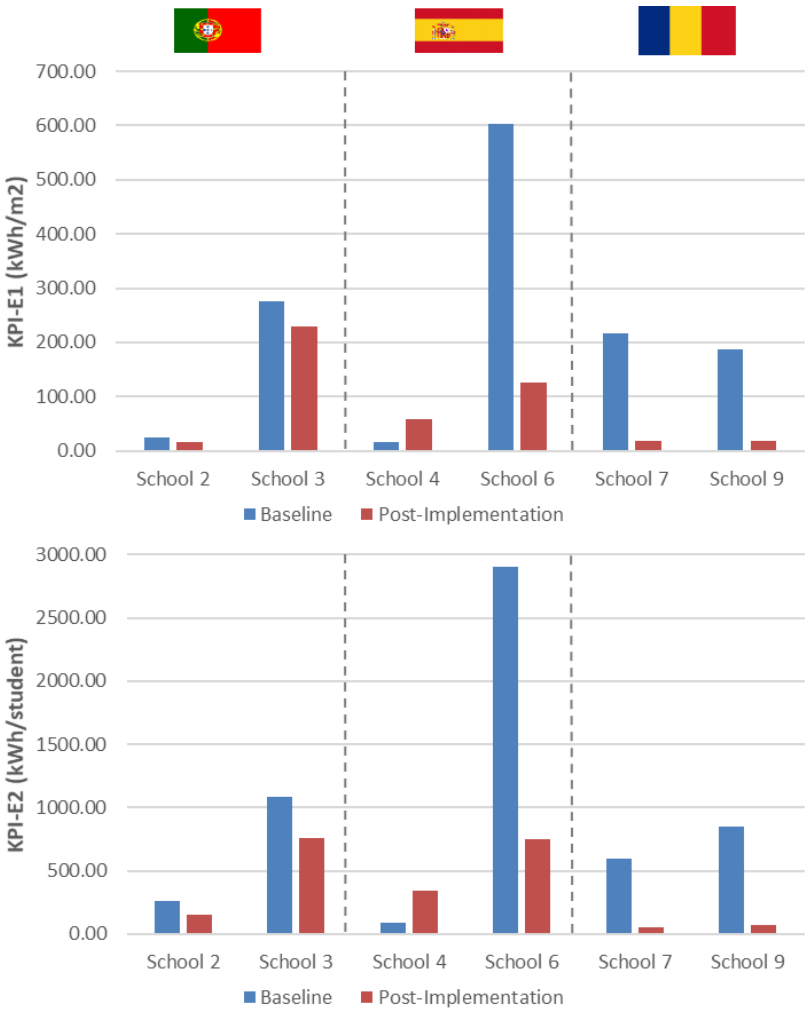

Figure 7 - KPIs results of the energy sector.

In contrast, Schools S2 and S7, representing primary and secondary education institutions, exhibit substantially lower energy use. Their lower consumption is consistent with their simpler building designs and shorter daily operating hours. These schools typically rely on natural ventilation without mechanical air conditioning, which, while limiting energy use, may compromise indoor comfort during colder months.

Figure 6 illustrates the post implementation energy consumption per m² and per student across these schools, highlighting these improvements compared to the baseline. The reductions, particularly notable in schools with initially high consumption, demonstrate the effectiveness of infrastructure upgrades and behavior change initiatives.

Baseline data showed significant variation among schools, with final energy consumption per square meter ranging from as low as 15.37 kWh/m² (S4) to very high values such as 602.10 kWh/m² (S6). Similarly, energy consumption per student varied greatly, with schools like S3 reaching values above 1,000 kWh/student, reflecting differences in school size, infrastructure, and usage patterns.

In the latest evaluation, most schools with available data (S2, S3, S6, S7, and S9) demonstrated reductions in energy consumption, both per area and per student. School S4 exhibited a slight increase in consumption

compared to baseline, which may be attributed to atypical usage patterns or external factors during the assessed year. For School S6, updated data indicates a substantial decrease in consumption per m² (from 602.10 to 124.91 kWh/m²) and per student (from 2902.48 to 746.72 kWh/student), reflecting ongoing challenges related to building characteristics but also the positive impact of technical interventions.

Figure 7 displays the energy consumption scores (0–5) for these schools, illustrating the improvements achieved, especially in institutions with initially high consumption, highlighting the effectiveness of the implemented technical and behavioral measures.

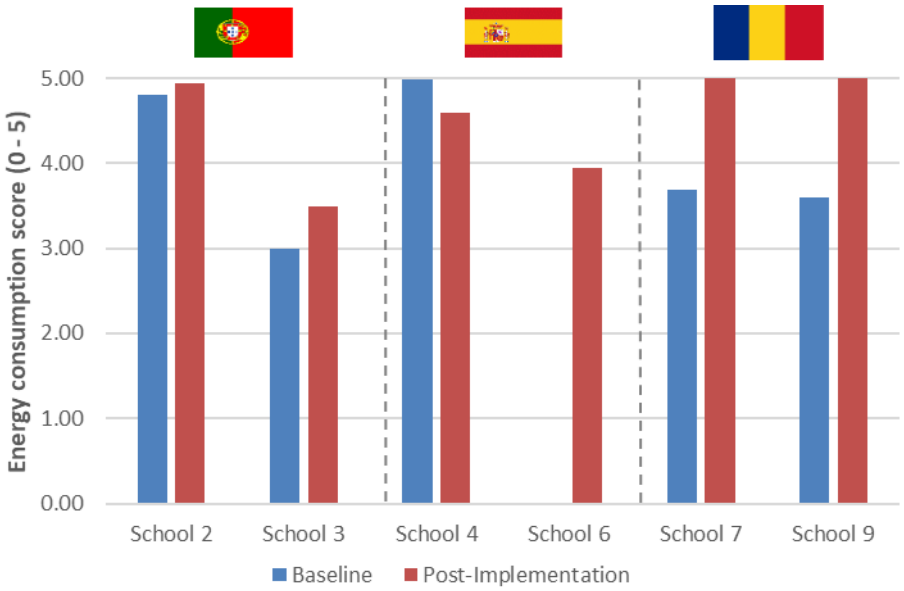

Figure 8 - Energy consumption score (0-5).

Renewable Energy Production

Although many demonstration sites installed photovoltaic systems, comprehensive data on renewable energy production is limited. Among schools reporting data, S2 and S3 lead with about 12% renewable energy share, followed by S9 with 10%. School S7 reports a modest 2.8%, while S6 currently has no recorded renewable production.

Correspondingly, renewable energy scores remain low for most schools, with S2 and S3 showing small improvements (from 0.0 to 0.6), reflecting early-stage adoption. This highlights potential for scaling up renewable generation and improving data monitoring.

Annual Carbon Emissions

Carbon emission KPI reveals substantial reductions, particularly in schools with higher initial carbon footprints. School S6 reduced its carbon emissions per student from 730.65 to 222.73 $kgCO_2$/year, while S3 dropped from 363.24 to 255.46 $kgCO_2$/year. These improvements reflect the combined impact of energy-saving interventions and initial steps toward renewable energy adoption. Carbon emissions scores improved accordingly: S6's score rose from 0.0 to 3.5, and S3 from 2.5 to 3.3, demonstrating clear progress. Lower-emission schools such as S7 also improved their scores, from 4.0 to 4.9.

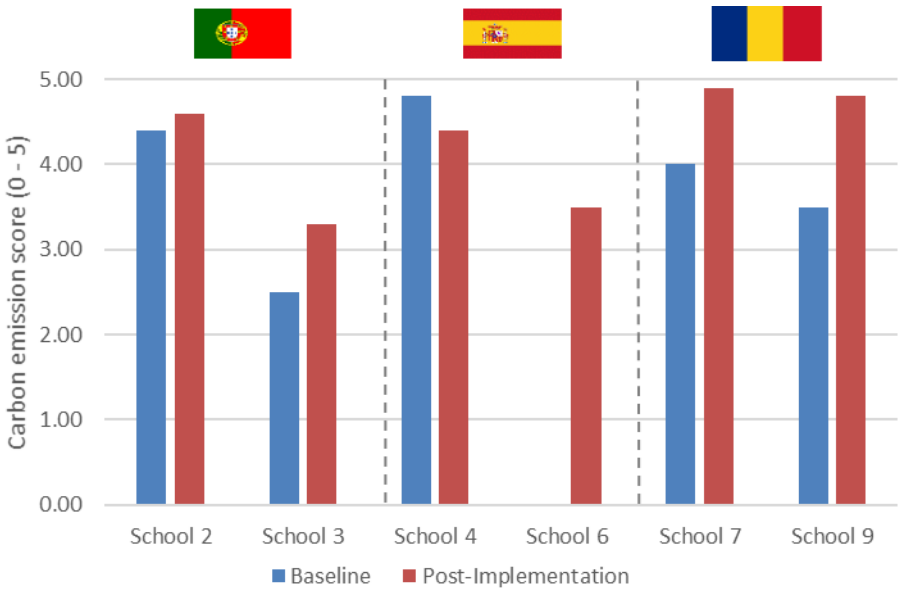

Figure 9 - Carbon emissions score (0-5).

The energy sector analysis highlights the importance of tailoring interventions to building type, usage patterns, and local climate. Infrastructure upgrades combined with educational engagement have produced measurable energy savings and emission reductions.

The energy consumption and cost scores show a mixed but overall positive trend: high-consuming schools are catching up through effective interventions, while low-consuming schools maintain good performance. Renewable energy scores reveal room for expansion.

Continued focus on renewable energy deployment, improved monitoring, and energy cost management will be essential to sustain and amplify these gains. Linking technical measures with education ensures that the culture of sustainability permeates school communities, supporting long-term impact.

Long-Term Environmental Impacts

Long-term benefits of the energy interventions extend beyond immediate consumption reductions to include cultural shifts and the embedding of sustainability values within the educational communities.

The installation of renewable energy infrastructure such as photovoltaic systems serves as a visible commitment to sustainability, fostering a culture where energy-conscious decision-making becomes the norm. Students exposed to hands-on learning and monitoring of such systems develop competencies and attitudes that influence their lifelong environmental behavior.

Energy efficiency upgrades contribute to lasting improvements in building performance and occupant comfort, encouraging schools to prioritize sustainable infrastructure investment in the future.

Educational programs that integrate sustainability concepts into curricula and promote engagement with renewable energy and efficient energy use nurture future citizens who are more aware of climate change mitigation and resource conservation.

These interventions collectively support a transition towards low-carbon educational environments and inspire wider societal change as students and staff become advocates for sustainable energy use within their families and communities.

6. Cross-sectoral Insights and Reflections

The broad evaluation of environmental interventions across the ECF4CLIM demonstration sites reveals profound cross-sectoral insights that underscore the interconnected nature of sustainability efforts within educational settings. While the project addressed distinct sectors—energy, waste, water, green spaces, air quality, and transport—through tailored measures adapted to local contexts, the cumulative effect highlights the vital importance of integrated approaches that leverage synergies to maximize environmental, educational, and social impact.

An example of this synergy is between energy conservation initiatives and sustainability education, where behavioral changes promoted through energy-saving measures also catalyzed improved practices in waste reduction and water conservation. Students engaged in energy awareness campaigns reported more attention to waste sorting and water use efficiency, illustrating how environmental literacy fosters reinforcing behavior changes that span multiple domains. This interconnection validates the potential of holistic education frameworks, such as GreenComp, which cultivate competencies that are transferable and applicable across environmental sectors, thus supporting more systemic sustainability progress.

Similarly, interventions focused on green spaces delivered multifaceted benefits by enhancing biodiversity, promoting wellbeing, and contributing indirectly to improved air quality and microclimate regulation. These natural co-benefits extend beyond isolated sectoral targets, illustrating the importance of considering ecological interrelations when designing sustainability measures. Complementarily, waste reduction campaigns supported resource conservation by lowering the demand for raw materials, with downstream effects that reduce energy and water consumption embedded in production and supply chains.

The integration of physical improvements—such as energy-efficient infrastructure, water-saving devices, enhanced waste sorting facilities, and the establishment of green areas—with educational initiatives was central to achieving persistent impact. Educational efforts instilled awareness and raised stewardship, creating a reinforcing feedback loop wherein increased knowledge inspires responsible actions, which in turn deepen learning and enhance community engagement. This dynamic interaction between infrastructure and education amplifies the overall effectiveness of sustainability interventions.

Long-term impacts, as documented through participatory projects and inclusive governance structures, are not limited to immediate environmental gains but also include transformative shifts in attitudes, daily routines, and institutional practices. Such changes embed sustainability into the operational DNA of schools, strengthening ownership, accountability, and the capacity for continual adaptation and improvement. Importantly, the educational dimension extends the reach of interventions beyond school boundaries, with students and staff acting as ambassadors who disseminate environmental values and behaviors into families and local communities. This multiplier effect is pivotal in fostering widespread societal change and ensuring the endurance of sustainability outcomes.

Nonetheless, several persistent challenges have emerged throughout the project. Variability in data availability and quality across sectors and schools limited the depth of quantitative assessment and comparability. Sustaining engagement of diverse stakeholders—including students, teachers, administrative

personnel, and local partners—proved demanding amid competing priorities and resource constraints. Maintaining momentum and institutionalizing interventions requires deliberate strategies to embed sustainability into policy, curriculum, and school culture, avoiding fragmented or isolated efforts.

Fostering cross-sector collaboration among environmental managers, educators, and community stakeholders is essential to harness multidimensional benefits and avoid duplication. Clear institutional pathways must be established to secure long-term sustainability integration within schools' operational frameworks.

In conclusion, the cross-sectoral perspective of the ECF4CLIM project affirms that education for sustainability is not a standalone objective but a foundational element that connects diverse environmental goals. It enables coordinated, resilient progress toward greener, healthier, and more engaged school environments, cultivating informed citizens equipped to drive sustainable transformation beyond the educational sphere.

7. CONCLUSION

The ECF4CLIM project exemplifies how targeted, intervention-driven approaches within educational institutions can generate meaningful improvements in environmental performance while simultaneously advancing sustainability education and fostering community engagement.

The mixed-methods evaluation combining quantitative KPIs and qualitative insights across sectors revealed tangible progress in resource use efficiency, waste management, green infrastructure enhancement, and environmental awareness. These advances were achieved despite varied data quality and external challenges.

Central to the project's success was the participatory co-creation of interventions, which empowered schools to tailor solutions to their unique contexts and capacities. This personalized approach cultivated strong stakeholder ownership, enhanced relevance, and facilitated behavioral change, with students, educators, and staff embracing sustainability as an integral part of school life.

Active participation by the school communities proved critical not only for implementation but for embedding sustainability values and practices that transcend project timelines. Student-led initiatives, peer education, and collaborative events fostered a culture of shared responsibility and proactive engagement, which schools anticipate will continue and expand.

Institutionalization of environmental monitoring and sustainability education emerged as a key factor for maintaining momentum. The project demonstrated that combining infrastructure upgrades with competence-building and awareness campaigns creates synergistic effects that reinforce environmental stewardship.

The lessons and methodologies developed through ECF4CLIM offer a replicable model for other educational settings seeking to integrate sustainability holistically. Emphasizing co-design, data-driven evaluation, and competency development ensures interventions are impactful, inclusive, and enduring.

In conclusion, ECF4CLIM's integrated, community-driven sustainability interventions highlight the transformative potential of schools as living laboratories for environmental action, nurturing informed, responsible citizens capable of contributing to a sustainable future.